PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

(Chapter II of the Patent Cooperation Treaty)

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference INTE-PA0302 WO	**FOR FURTHER ACTION**	See Form PCT/IPEA/416
International application No. PCT/DK2004/000555	International filing date *(day/month/year)* 19.08.2004	Priority date *(day/month/year)* 19.08.2003
International Patent Classification (IPC) or national classification and IPC G02B6/30		
Applicant NKT INTEGRATION A/S et al.		

1. This report is the international preliminary examination report, established by this International Preliminary Examining Authority under Article 35 and transmitted to the applicant according to Article 36.
2. This REPORT consists of a total of 5 sheets, including this cover sheet.
3. This report is also accompanied by ANNEXES, comprising:
   a. ☒ *sent to the applicant and to the International Bureau)* a total of 5 sheets, as follows:
      ☒ sheets of the description, claims and/or drawings which have been amended and are the basis of this report and/or sheets containing rectifications authorized by this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions).
      ☐ sheets which supersede earlier sheets, but which this Authority considers contain an amendment that goes beyond the disclosure in the international application as filed, as indicated in item 4 of Box No. I and the Supplemental Box.
   b. ☐ *(sent to the International Bureau only)* a total of (indicate type and number of electronic carrier(s)) , containing a sequence listing and/or tables related thereto, in computer readable form only, as indicated in the Supplemental Box Relating to Sequence Listing (see Section 802 of the Administrative Instructions).

4. This report contains indications relating to the following items:

☒	Box No. I	Basis of the opinion
☐	Box No. II	Priority
☐	Box No. III	Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
☐	Box No. IV	Lack of unity of invention
☒	Box No. V	Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
☐	Box No. VI	Certain documents cited
☐	Box No. VII	Certain defects in the international application
☐	Box No. VIII	Certain observations on the international application

Date of submission of the demand	Date of completion of this report
14.06.2005	11.08.2005
Name and mailing address of the international preliminary examining authority: European Patent Office - P.B. 5818 Patentlaan 2 NL-2280 HV Rijswijk - Pays Bas Tel. +31 70 340 - 2040 Tx: 31 651 epo nl Fax: +31 70 340 - 3016	Authorized Officer Faderl, I Telephone No. +31 70 340-3455

INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

International application No.
PCT/DK2004/000555

Box No. I Basis of the report

1. With regard to the **language**, this report is based on the international application in the language in which it was filed, unless otherwise indicated under this item.

   ☐ This report is based on translations from the original language into the following language , which is the language of a translation furnished for the purposes of:
   - ☐ international search (under Rules 12.3 and 23.1(b))
   - ☐ publication of the international application (under Rule 12.4)
   - ☐ international preliminary examination (under Rules 55.2 and/or 55.3)

2. With regard to the **elements*** of the international application, this report is based on *(replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report)*:

Description, Pages	
1-43	as originally filed
Claims, Numbers	
1-28	received on 14.06.2005 with letter of 14.06.2005
Drawings, Sheets	
1/7-7/7	as originally filed

   ☐ a sequence listing and/or any related table(s) - see Supplemental Box Relating to Sequence Listing

3. ☐ The amendments have resulted in the cancellation of:
   - ☐ the description, pages
   - ☐ the claims, Nos.
   - ☐ the drawings, sheets/figs
   - ☐ the sequence listing *(specify)*:
   - ☐ any table(s) related to sequence listing *(specify)*:

4. ☐ This report has been established as if (some of) the amendments annexed to this report and listed below had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2(c)).
   - ☐ the description, pages
   - ☐ the claims, Nos.
   - ☐ the drawings, sheets/figs
   - ☐ the sequence listing *(specify)*:
   - ☐ any table(s) related to sequence listing *(specify)*:

* *If item 4 applies, some or all of these sheets may be marked "superseded."*

Box No. V Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1-28
	No:	Claims	
Inventive step (IS)	Yes:	Claims	1-28
	No:	Claims	
Industrial applicability (IA)	Yes:	Claims	1-28
	No:	Claims	

2. Citations and explanations (Rule 70.7):

see separate sheet

Re Item V

Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

Reference is made to the following documents:

D1: US-B1-6 181 860 (SVENSSON PER JOHAN OLOF ET AL) 30 January 2001 (2001-01-30)

D2: WO 03/062883 A (LIPSON MARK ;CORNELL RES FOUNDATION INC (US); DE ALMEIDA VILSON RO) 31 July 2003 (2003-07-31)

The document D1 and D2 are regarded as being the closest prior art to the subject-matter of claim 1, and show:

An optical component comprising a combination of optical waveguide elements for modifying the spot size of a mode of an electromagnetic field propagated by an optical waveguide element, the optical waveguide elements being formed on a substrate, the optical component comprising a) a first section, comprising a first optical waveguide element adapted to sustain at least one mode of the electromagnetic field, b) a second section comprising at least two cooperating optical waveguide elements, each of said at least two cooperating optical waveguide elements comprising at least one waveguide segment, said at least two cooperating optical waveguide elements being optically connected to said first optical waveguide element of said first section; wherein said cooperating optical waveguide elements of said second section are adapted to maintain optical coupling between said optical waveguide elements to ensure that said at least one mode of the electromagnetic field is sustained by said at least two cooperating optical wavegulde elements in cooperation, and said first optical waveguide element and said at least two cooperating optical waveguide elements are tapered to increase in width towards their common interconnection, the tapering being smooth and containing no discontinuities in the width, angle or the radii of curvature of the optical waveguide elements,

The subject-matter of claim 1 differs from D1 or D2 in that the tapering of at least one of the edges of the first optical waveguide element and at least one of the edges of the at

least two cooperating optical waveguide elements in a direction substantially parallel to the direction of propagation of the electromagnetic field of the optical waveguide element in question are defined by a generating curve essentially following a trigonometric functional path, such as a cosine path, or an nth order polynomial path of at least 5th order, such as a 5th or a 7th order polynomial path.

The subject-matter of claim 1 is therefore new (Article 33(2) PCT).

The problem to be solved by the present invention may be regarded as how to improve the optical loss of such a beam shape adapting element.

The solution to this problem proposed in claim 1 of the present application is considered as involving an inventive step (Article 33(3) PCT) as this type of optical transistion curve is neither suggested nor evident in one of the prior art documents. Even though D2 suggests that the taper may have any geometry (see page 5, line 11-17), there is no clear indication why the person skilled in the art should chose a cosine path or a 5th or 7th order polynomial. Therefore the solution disclosed in the application is not evident and inventive.

Claims 2-28 are dependent on claim 1 and as such also meet the requirements of the PCT with respect to novelty and inventive step.

CLAIMS

1. An optical component comprising a combination of optical waveguide elements for modifying the spot size of a mode of an electromagnetic field propagated by an optical waveguide element, the optical waveguide elements being formed on a substrate, the optical component comprising a) a first section, comprising a first optical waveguide element adapted to sustain at least one mode of the electromagnetic field, b) a second section comprising at least two cooperating optical waveguide elements, each of said at least two cooperating optical waveguide elements comprising at least one waveguide segment, said at least two cooperating optical waveguide elements being optically connected to said first optical waveguide element of said first section; wherein said cooperating optical waveguide elements of said second section are adapted to maintain optical coupling between said optical waveguide elements to ensure that said at least one mode of the electromagnetic field is sustained by said at least two cooperating optical waveguide elements in cooperation, and said first optical waveguide element and said at least two cooperating optical waveguide elements are tapered to increase in width towards their common interconnection, the tapering being smooth and containing no discontinuities in the width, angle or the radii of curvature of the optical waveguide elements, and wherein the tapering of at least one of the edges of the first optical waveguide element and at least one of the edges of the at least two cooperating optical waveguide elements in a direction substantially parallel to the direction of propagation of the electromagnetic field of the optical waveguide element in question are defined by a generating curve essentially following a trigonometric functional path, such as a cosine path, or an n^{th} order polynomial path of at least 5^{th} order, such as a 5^{th} or a 7^{th} order polynomial path.

2. An optical component as claimed in claim 1 wherein the tapering of said first optical waveguide element of said first section is defined by a generating curve essentially following a cosine path or an n^{th} order polynomial path, such as a 5^{th} or a 7^{th} order polynomial path.

3. An optical component as claimed in claim 1 or 2 wherein adjacent of said at least two cooperating optical waveguide elements of said second section have mutual edge to edge core distances $s_{2,i,i+1}$, and wherein said edge to edge core distances $s_{2,i,i+1}$ decrease towards their connection to said first optical waveguide element of said first section.

4. An optical component as claimed in any one of claims 1-3 wherein the tapering of at least one of said cooperating optical waveguide elements of said second section is defined by a generating curve essentially following a cosine path or an n^{th} order polynomial path, such as a 5^{th} or a 7^{th} order polynomial path.

5. An optical component as claimed in any one of the preceding claims wherein the width w_1 of said first optical waveguide element of said first section is larger than or equal to the sum of widths $w_{2,i}$ of said cooperating optical waveguide elements of said second section at their mutual connection.

6. An optical component as claimed in any one of the preceding claims wherein said at least two cooperating optical waveguide elements of said second section are adapted to be optically coupled to an output optical waveguide.

7. An optical component as claimed in claim 6 wherein said output optical waveguide is formed on said substrate.

8. An optical component as claimed in any one of the preceding claims, the optical component further comprising c) a third section comprising at least two dicing optical waveguide elements having core widths $w_{3,i}$, said at least two dicing optical waveguide elements being optically connected to said at least two cooperating optical waveguide elements of said second section.

9. An optical component as claimed in claim 8 wherein said at least two dicing optical waveguide elements are essentially straight and parallel.

10. An optical component as claimed in claim 9 wherein the widths $w_{3,i}$ of said at least two dicing optical waveguide elements of said third section remain essentially constant.

11. An optical component as claimed in any one of claims 8-10 wherein the widths $w_{2,i}$ of said at least two cooperating waveguides of said second section essentially equals the widths $w_{3,i}$, where i=1, 2, ..., of said at least two dicing optical waveguide elements of said third section at their mutual connection.

12. An optical component as claimed in any one of claims 8-11 wherein said at least two dicing optical waveguide elements of said third section are adapted to be optically coupled to an output optical waveguide.

13. An optical component as claimed in claim 12 wherein said output optical waveguide is an optical fibre, such as a single mode fibre, e.g. an SMF-28 type optical fibre.

14. An optical component as claimed in any one of the preceding claims wherein said first optical waveguide element of said first section is adapted to be optically coupled to an input optical waveguide, said input optical waveguide having a width w_{in} which is essentially equal to the width w_1 of said first optical waveguide element at their mutual connection.

15. An optical component as claimed in claim 14 wherein said input optical waveguide is formed on said substrate.

16. An optical component as claimed in any one of the preceding claims wherein said combination of optical waveguide elements comprises a base layer formed on said substrate, the base layer having a refractive index n_{base}, a waveguide defining core pattern of a core material formed on the base layer, the core material having a refractive index n_{core}, an upper cladding layer covering the core pattern and the base layer, the upper cladding layer having a refractive index n_{uclad}.

17. An optical component as claimed in claim 16 wherein the index contrast between core and cladding and/or core and base layers $(n_{core}-n_{uclad})/n_{core}$, $(n_{core}-n_{base})/n_{core}$, respectively, is larger than 0,5 %, such as larger than 1%, such as larger than 2%

18. An optical component as claimed in any one of the preceding claims wherein at least one transversal waveguide core element is arranged between said at least two cooperating optical waveguide elements of said second section.

19. An optical component as claimed in claim 18 wherein a multitude of M transversal waveguide core elements each having a width $w_{t,j}$, where j=1, 2, ..., M, and forming paths with a mutual centre to centre distance of $s_{t,j,j+1}$, where j=1, 2, ..., M-1, j=1 corresponding to the transversal element located closest to said first section and j=M corresponding to the transversal element located farthest from said first section.

20. An optical component as claimed in claim 19 wherein said widths $w_{t,j}$ decrease with increasing j and/or said centre to centre distances of $s_{t,j,j+1}$ increase with increasing j.

21. An optical component as claimed in any one of the preceding claims wherein said core material comprises a material from the group GaAs, InP, SiON, Silicon, polymers, sol-gel glasses, $LiNbO_3$.

22. An optical component as claimed in any one of claims 16-21 wherein the optical waveguide elements comprises a base layer formed on the substrate, a waveguide-defining core pattern of a core material formed on the base layer and an upper cladding layer covering the core pattern and the base layer.

23. An optical component as claimed in any one of the preceding claims wherein the core regions of the optical waveguide elements of the second section are implemented in the same physical layer and continue into the core region of the first optical waveguide element of the first section of the optical component.

24. A method of manufacturing an optical component according to any one of claims 1-23, the method comprising the steps of

a) providing a substrate,

b) forming a lower cladding layer on the substrate,

c) forming a core layer on the lower cladding layer,

d) providing a core mask comprising a core region pattern corresponding to the layout of the core regions of optical waveguide elements of the component,

e) forming core regions using the core mask, a photolithographic and an etching process, and

f) forming an upper cladding layer to cover the core region pattern and the lower cladding layer,

25. A method according to claim 24, the method further comprising the steps of

g) cutting the dicing waveguides of the third section of the components

h) dicing/polishing the end facets of said dicing waveguides.

26. A method according to claim 24, the method in step d) further comprising the sub-step of

d1) providing that the tapering of the core region of said first waveguide element of said first section and/or at least one of said cooperating optical waveguide elements of said second section of said optical component is/are defined by a generating curve essentially following a cosine path or an n^{th} order polynomial path, such as a linear path or a 5^{th} or a 7^{th} order polynomial path.

27. A method according to claim any one of claims 24-26 wherein the substrate is a silicon substrate, the base and cladding layers comprise silica based oxides and the core layer comprises silicon-oxy-nitride.

28. A method as claimed in any one of claims 24-27 wherein the formation of layers on the substrate is made by plasma enhanced chemical vapour deposition.